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THE AERODYNAMIC SAFETY OF AIRPLANES

By Louis Kahn

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Aeronautic activity in Europe is now divided between military, commercial and private aviation in the propor- tion of 15-4-1. Thus 19 airplanes out of every 20 are flown daily by professional pilots. The future of avia- tion depends largely on changing this proportion in favor of the third term. In effect, all military aviation and the greater part of commercial aviation are separated from industry by a screen. They are not free technically nor financially. To borrow from the language of economics, they are being developed under a régime of regulated tech- nics. The constructor therefore lacks the decisive guide, namely the requirements of private customers. It is by creating a public demand for aviation that more rapid progress will be made in solving the problems of safety.

Without doubt, safety is already confounded with ef- ficiency in both military and commercial aviation. The crux for both lies in the conditions for the performances and for the weight lifted. The designer is concerned about the development of a few additional feet of climbing speed, which will determine the mastery of the air on the day of battle, or for civilian airplanes, with the addition of a few pounds of pay load per horsepower, which will distin- guish a good airplane from a mediocre one.

Since, however, the pilot is intimately acquainted with the reactions of his airplane and since he is governed by an organization whose accumulated experience serves him even during the execution of his mission, some imperfec- tions in flying and landing qualities are tolerated.

The case is not the same with an airplane for a pri- vate customer who is not protected by a system of custom and regulations. From this viewpoint, it is necessary to distinguish the accidental risk and the specific risk.

A craft that travels at 200 km (124 miles) per hour will always be dangerous in case of collision. For an airplane the risk of collision is less than for most vehicles, but the results are more serious. The risk here is exceptional.

On the contrary, the capsizing of an airplane in a forced landing and stalling above an encumbered terrain are not exceptional, save in their causes, the breakdown of the engine or a sudden meteorologic disturbance. If the result is serious, it is because the landing speed of the airplane is too close to its maximum speed, or because it is not controllable enough at large angles of attack. This is a specific danger.

Statistics show that fire, collisions, the failure of a structural part and the meeting of obstacles, in short, the considerable number of exceptional causes account for only 40 per cent of aerial accidents.

On the contrary, specific risks account for 60 per cent of the accidents. Hence it was decided to discuss them in this article, because aerodynamic risks involve the engineers, while the exceptional risks depend chiefly on the user.

The time has passed when any particular risk was acknowledged for a boat due to the fact that it is a floating body. Accidents at sea are no longer due to the principle of Archimedes, but to fog, to stranding and to tempests.

If airplanes still suffer from owing their support and equilibrium to their speed, it must be remembered that, at twenty years of age, it is developing too rapidly for accurate predictions as to its future.

I

Landing.- Length of horizontal flight near ground, which is but slightly affected by the fineness ratio, the essential fact being the margin of safety between the remaining speed and the minimum speed.
Taking off.- Degree of loss of lateral controllability at large angles of attack.
Stability and controllability.- Criteria. Controlled piloting. Tests with models mounted wind-vane fashion. Tests with free models.

Flight tests.- Need of deductive publications.

In order to land at as low a speed as possible, an airplane must lose its excess speed while flying horizontally very close to the ground, i.e., about three feet. It is this horizontal flight which increases the landing distance and its uncertainty. The phase of oblique descent preceding it and the phase of taxying, which follows it, leave the pilot relatively free. On the contrary, the length of the horizontal flight depends entirely on the original conditions. It is made at uniform lift, the pilot stalling the airplane as the speed decreases.

Thus the lift $\frac{a}{2\,g} C_z V^2 S$ remains constantly equal to the weight P, while the speed is reduced by the drag $R = \frac{a}{2\,g} C_x V^2 S$. The distance l, traversed in the air, is defined by the expression $\frac{P}{g} VdV = Rdl$, which indicates that the work of the structural drag equals the loss in the kinetic energy of the airplane. On noting that the constancy of the lift entails

$$\frac{dC_z}{C_z} + \frac{2\,dV}{V} = 0$$

we finally obtain

$$l = \frac{P}{aS} \int \frac{dC_z}{C_z C_x}$$

for the length of the horizontal landing flight, the integral being taken between the C_z corresponding to the beginning of the horizontal flight, (fig. 1) i.e., the speed at the end of the descent, on the one hand, and the C_z near the C_z maximum which corresponds to the minimum landing speed, on the other hand. This formula indicates that the length of the horizontal landing flight depends on three considerations:

a) It is proportional to the wing loading and consequently to the weight for a given airplane;
   b) It depends on the form of the airplane polar;
   c) It is shorter in proportion as the airplane, while still some distance above the ground, is able to

approach the maximum angle of attack without danger of stalling.

In Figure 1 the C_z are the absicissas. The two heavy curves indicate the values of the LC_z for an airplane reduced to its wing alone, with an L/D ratio of 11.8. It is seen that the two curves differ but little within practical angles of attack, i.e., to the right of the vertical dot line. The dot-dash line indicates the angle of attack in terms of C_z. The dash line marks the reduction in speed. The coefficient u on the ordinate is the square root of the ratio of C_z max to the value of C_z at each point.

In order to illustrate these considerations, we will apply them to a particular airplane. We will suppose it to have the wing section 73A of the Technical Section of Aeronautics (C_z max, 1.332; aspect ratio, 6; maximum L/D, 19.38 at an angle of attack 2.85° for a C_v of 0.388). We will assume the same C_z for the airplane as for the wing section alone at the same angles of attack. We will pass from the polar of the wing section to the polar of the airplane by a transition parallel to the axis of C_x which reduces the maximum L/D to 11.8 for an angle of attack of 0.3°. The formula for the length of horizontal landing flight is then

$$l = \frac{P}{aS} \; L(C_z)$$

L being a numerical function of C_z as defined by

$$L(C_z) = \int_{C_z}^{C_zM} \frac{d \, C_z}{C_x C_z}$$

in which C_zM represents the maximum value of C_z. The values of L can be determined graphically for the chosen airplane from the following data:

C_z at beginning of level flight	1.33	1.1	1	0.6
Corresponding angle of attack (deg.)	15	7.2	5.6	0.2
L for wing section	0	1.5	2.55	13.5
L for airplane	0	1.2	2	9.5
Effective length of level flight for airplane (m)	0	60	100	470

The following table gives the lengths of the horizontal landing flights for two airplanes, one having an L/D of 11.5 and the other 19.5, for different speeds at the beginning of the horizontal flight and in landing.

SPEED (km/h)		LENGTH OF LEVEL FLIGHT (m)	
Beginning of level flight	Landing	L/D = 11.5	L/D = 19.5
116	108	40	52.5
116	82	100	127.5
108	82	60	75

When the wing area is reduced, i.e., when the maximum fineness ratio L/D is almost doubled, the length of the level landing flight is increased but slightly. The effect of the fineness of the airplane is therefore slight, which is contrary to an often-expressed idea. It is not because an airplane is "fine" that it "refuses to settle," but because it does not inspire its pilot with sufficient confidence to approach the ground at a high angle of attack.

The most effective way to reduce the length of the landing flight is, according to the above table, to land at a speed slightly above the minimum speed, but the airplane may then rebound because of its too-low angle of attack (below 7.8°). This method presupposes a particular arrangement of landing gear and tail skid, but renders it possible to add to the aerodynamic braking force (which, for the airplane considered, is about an eighth of its weight) an almost equal force due to the braking effect of the wheels.

On the contrary, it is seen that loss of fineness of the airplane shortens the horizontal landing flight but little. In passing from an airplane with a maximum L/D of 19.5 (case of wing section chosen) to an airplane with a maximum L/D of 11.5, the horizontal flight is shortened, for the same angle of entering it, by 12.5 m (41 ft.), 27.5 m (90 ft.) and 15 m (49 ft.). Lastly we recall that the above figures must be increased for an airplane with a greater wing loading and in proportion to the load*.

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*In this calculation we disregarded the action of the contrary wind, which has a double effect: first, to permit contact with the ground at a higher air speed; second, to

In order to take off within a short distance, it is likewise important for the pilot to be able to approach, without danger, the angle of maximum lift, but we shall not dwell on this well-established point.

The loss of lateral controllability, which always precedes a spin, requires a more difficult analysis, on which we would like to dwell. This is, in fact, the principal obstacle to the use of high angles of attack. At these angles the aerodynamic forces at the disposal of the pilot for producing a restoring moment about the c.g., are reduced as the square of the speed, but, in particular, they are no longer sensitive to variations in the deflection of the control surfaces. Even if the aileron controls are rigidly held, the lateral trim of the airplane is not affected.

In order to have a definite basis for our reasoning, we will utilize wind-tunnel data showing the effect of the deflection of the trailing edge on the lift of the wing section*.

The effect of the lateral controllability, due to the action of the differentially deflected ailerons, may be calculated from the difference in the C_z of the corresponding wing profiles. We will therefore study the evolution of this difference for a given angle of deflection, when the mean angle of attack of the profile is increased. Two maneuvers must be considered. First, we may suppose a sudden disturbance, increasing the angle of attack, without there being time for the speed to vary appreciably. Such would be the case of a rapidly executed spinning nose dive. In a second case, we will suppose that the pilot keeps his airplane at constant lift by gradually increasing the angle of attack, either because he has poor visibility or is trying to reduce his speed at too high an altitude to land on a small field, a circumstance which may

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(Continued from bottom of page 5.)
shorten the horizontal flight by the distance traversed by the opposing wind during this flight, as represented by the expression

$$\frac{w}{\sqrt{2g}} \; \sqrt{\frac{P}{aS}} \int \frac{dC_z}{C_x \sqrt{C_z}}$$

in which w is the velocity of the wind.
* Bulletin du Service Technique de l'Aéronautique, No. 25 February, 1925, profiles 111A1, 111A2, 111A3.

cause the airplane to stall. Then the moment of control-
lability is no longer reduced simply as the difference in
the C_Z values, but as the quotient of this difference
divided by the C_Z of the whole wing.

An intentional climb, followed by a spin, is interme-
diate between these two extremes. In Figure 2 the index
of controllability μ is plotted against the angle of at-
tack of the wing. The ordinate unit corresponds to an
airplane with a wing loading of 60 kg/m^2 (12.3 lb./sq.ft.)
at a speed of 200 km (124 miles) per hour and a maximum
L/D ratio of 12 at zero angle of attack. The reduction
in controllability is represented by the ratio of the or-
dinates to the ordinate unit. Curve 1 represents a sudden
climb, while curve 2 represents the gradual loss of speed.
On the latter curve we have also indicated the correspond-
ing speed for each point. Moreover it is easy to calcu-
late the law of the corresponding times.

In further reference to Figure 2, the laboratory
measured the C_Z of both wings derived from the wing 111A
by deflecting the trailing edge in the opposite direction,
as in the action of the ailerons. We then characterized
the coefficient of controllability μ by the difference
in the C_Z of these two wings, i.e., by a quantity pro-
portional to the moment due to the ailerons. (Of course
this disregards many effects, and it can not be assumed,
with a difficult approximation, that the two semiwings are
separated.) The difference in the C_Z is referred to the
C_Z of the wing supposedly mounted on an airplane making
200 km (124 miles) an hour, with a wing loading of 60 kg/m^2
(12.3 lb./sq.ft.). Curve 1 represents a sudden disturb-
ance which does not affect the speed. Curve 2 represents
a gradual disturbance at constant lift. It is seen that,
for large angles, μ approaches zero, and that, it prob-
ably becomes negative at certain high incidences, i.e.,
that the aileron control is reversed after a period during
which it has practically no effect.

In Figure 3 the index of controllability μ is
plotted against the time in seconds, the characteristic
phenomenon being here completely analyzed in 26 seconds.
If we examine in particular what takes place after the
speed drops below 160 km (about 100 miles) per hour, we
find that it takes about 15 seconds for the speed of the
airplane to drop from 160 to 118 km (100 to 73 miles) per
hour, while the lateral controllability diminishes uni-
formly and almost inappreciably. It is slight during the

two seconds following the drop in speed from 118 to 111
km (69 miles) per hour, but is accompanied in less than a
second by the complete destruction of the lateral stabil-
ity*.

The numbers on the curve indicate the speed in km/h.
Note the gradual variation of μ up to the last phase,
where the variation is very sudden for only a slight re-
duction in speed. The phenomenon would have been still
clearer, if, instead of assuming a maneuver at constant
lift, we had assumed that the airplane was descending,
i.e., that the phenomenon was accompanied by a reduction
in the lift. Lateral controllability becomes all the more
necessary, as the lateral stability decreases greatly at
low speeds. This is due to the fact that the restoring
moment appears only after the beginning of the sideslip
which follows the transverse inclination and that it is
produced not by the amount of the inclination, but by the
velocity of slipping. This simple example illustrates the
particular phenomenon in aviation in the questions of sta-
bility and controllability. It is impossible to combine
them in a single notion like, e.g., that of the lever arms
of moments of stability in ships, a notion which, after
centuries of empiricism, has assumed in a very short time,
a canonical form applicable to the operations of profes-
sional calculators.

In aviation we have not arrived at the idea, perhaps
indiscoverable, of a single satisfactory criterion. This
criterion should have two qualities. First, it should
yield, without question, good qualities of flight. Sec-
ondly, it should be possible to apply it to airplanes with

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*We will not enter into the details of the spin, but it may
be conceived that this drop to zero is followed by the in-
version of the effect of the aileron control and that it
will not resume its normal action until the mean angle of
attack of the airplane becomes small enough for the repre-
sentative point of the controllability to be described in
the inverse direction of the curve in Figure 2. This phe-
nomenon may be aggravated by two conditions: 1. When the
phenomenon occurs with decreasing lift, i.e., with a cer-
tain sinking of the airplane; 2. When the airplane is
less "fine" than the one considered, because the descent
of the speed curve is then even more rapid.

the assurance that the supplementary conditions would not condemn excellent aircraft, nor render the airplanes impossible to construct. The criterion must be valid for attitudes differing decidedly from the position of equilibrium, because recovery must be possible from any position after a controlled maneuver, atmospheric disturbance, poor visibility or faulty piloting. It must also hold good for the very large speed range of the airplane and for the proximity of the ground, i.e., for the recovery of the airplane within as short a fall as possible. Such a problem can not be solved by the simple method of a test or calculation, but by a number of subjective tests and precautions in piloting and in the arrangement of the controls. The available data are:

a) The organization of the controlled piloting renders it possible to keep the airplane in the vicinity of its position of equilibrium, even in the event of serious atmospheric disturbances. This organization can be applied successfully only to airplanes already possessing a high degree of stability, lacking which, in case of bad weather, the pilot is guided by his instruments*.

b) Laboratory tests called wind-vane tests. These are based on the two following hypotheses:

First hypothesis.- The nondimensional coefficient

$$C_M = \frac{M}{\frac{a}{2g} V^2 St}$$

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* It only retards the solution of this problem to mount such devices on unstable airplanes, on the pretext of increasing the range of the demonstrations. In fact many airplanes "fly of themselves" in calm weather, without instruments, while even stable airplanes sometimes fly badly in rough weather. A stable airplane furnishes its own principal restoring moments, the controls being only supplementary. On an unstable airplane the restoring moments are constantly dividing. The best thing to do with an unstable airplane is not to provide it with stabilizing instruments or automatic control, but to condemn it and replace it by a stable airplane.

(in which M is the restoring moment about the c.g., a,
the weight of a liter (61 cu.in.) of air; g, the accel-
eration due to gravity; V, the speed; S, the wing area,
and t the wing chord) is independent of the speed and of
the absolute dimensions of the model.

Second hypothesis.- The airplane will be stable, if,
for every setting, this coefficient is an increasing func-
tion of the angle of deflection, the derivative not going
below a certain value at the maximum and minimum setting.

We do not wish to dwell on the questions occasioned by
these hypotheses*. The engineer's viewpoint is not the
same as that of formal logic, and two reasons justify the
use made of their conclusions. On one hand the airplanes
which occasioned the most serious aerodynamic accidents
(nine in a single year) would have been discarded by the

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* At its last three meetings the A.T.M.A. (Association
Technique Maritime et Aéronautique) devoted several ses-
sions to the problems of stability. There was first pub-
lished, in the bulletin of 1929, a paper by Volmerange,
an engineer in the Service Aéronautique du Bureau Veritas,
entitled "Les qualités aerodynamiques des avions et la sé-
curite," p. 329. In 1930, Volmerange published another
paper "Notion de stabilité et l'avion" (1930 bulletin, p.
309). These important papers may be considered as the ba-
sis of the constructional regulations of the Bureau Veri-
tas ("Réglement pour la construction et la classification
des aéronefs pour 1931," p. 116). These two bulletins con-
tain discussions by Leroux, Roy and the writer of the pres-
ent article.

In 1931, Lapresle, an aeronautic engineer, contributed
to the A.T.M.A. a paper "Sur l'examen critique de la méth-
ode de la girouette pour le controle au laboratoire aéro-
dynamique de la stabilite de forme des avions." This meth-
od, which was reduced to its present form under the direc-
tion of A. Lapresle, was published by him in the Bulletin
du Service Technique de l'Aéronautique, No. 66, February,
1930. (For translation, see N.A.C.A., T.M. No. 607.)

Also in 1931, Leroux, an aeronautic engineer, discussed
the question of stability in a paper, "Contribution a
l'etude du vol de l'avion dans un plan vertical," as like-
wise Roy in his "Etude theórique et expérimentale de la sta-
bilite des régimes de vol des avions." These papers, to-
gether with the discussions occasioned by them, are in
course of publication.

wind-vane test. On the other hand, when the model of an airplane is subjected to this test at the same time the engineer is designing it, there follows no condition incompatible with the program of the utilization of the airplane. We think, however, that it would be greatly improved by the following measures.

The use of the absolute coefficient C_m disregards one essential phenomenon, namely the effect of the speed on the moments*, the decisive effect of which has been shown in the matter of controllability. This effect must be taken into account, because it increases the stabilizing moments at small angles of attack and decreases them at large angles, and also because it is not certain that, for different airplanes designed for different speeds, the use of absolute coefficients will suffice, as for the polar. It would also be preferable to determine the curve C_m for a speed corresponding to each angle of attack. The normal speed of the airplane would be taken as the basis, and the coefficient C_{mc} would be replaced by

$\dfrac{C_{mc} \times C'_z}{C_z}$, in which C'_z corresponds to the basic speed**.

It would then be necessary to adapt the curve to the study of stability for finite deflection angles, which would require quite a number of supplementary measurements, taking account of the setting of the controls in each case.

It would finally be necessary to determine simultaneously the sensitiveness of the controls, i.e., the moment produced by varying their deflection and the moment produced on the airplane by a given force on the control stick. To a certain extent, in fact, small stabilizing moments can be accepted in regions where the sensitiveness of the controls remains unimpaired, while the contrary case can not be accepted.

These are all the elements which can be expected from the wind-vane tests, i.e., from an elementary investigation

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*This effect was noted by Lapresle in his communication to the A.T.M.A. in 1931, already referred to.
**Simple question of plotting the curves, because the determinations would not thereby be rendered more difficult.

in which the c.g., is supposed to be fixed and no account
is taken of the distribution of the masses in the air-
plane, but simply of their center, when the effect of the
propeller slipstream is entirely disregarded and when the
similarity of the differential effects of the surfaces of
the airplane is assumed. These reservations indicate,
however, that they can not suffice for the airplane it-
self, so that three groups of no less indispensable sup-
plementary tests must be added to the above data a and b:

    c) Tests on small models freely mounted;
    d) Tests on airplane prototypes;
    e) Constant study of the operating conditions of air-
planes produced in quantity.

    In order not to exceed the limits of this paper, we
will dwell on only two points, while referring our readers
to the A.T.M.A. for further details. Experimentation with
small models seems to be necessary, particularly in inves-
tigating airplanes having decidedly novel transverse di-
mensions and mass distribution. The problem is less to de-
termine analytically the strict conditions of similarity,
than those yielding the greatest degree of safety without
involving the construction of the airplane in too many sup-
plementary conditions.

    In single-engine airplanes of nearly the same weight,
the small-model test indicates a process of recovery al-
most identical for all the airplanes with the same initial
attitude. The airplane dives until it has regained its
speed in its diametral plane, when its longitudinal stabil-
ity tends to restore it to its line of flight. The spin
would appear possible only for an airplane having its cen-
ter of gravity toward the rear and widely distributed
masses. Directional stability at large angles would thus
appear to be the fundamental aerodynamic condition.

    It seems that one of the principal consequences of
experimentation on small free models would be to determine
the effect of the ratio of the radius of gyration to the
lever arms of the stabilizing moments, a ratio which varies
with the speed* and with the incidence, and, in particular,
to classify the airplanes by the falling distance necessary
for levelling off under critical conditions. The advan-
tages of the small-model method are therefore as follows.

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* The lever arm of the stability moments is the quotient
of the moments divided by the weight of the airplane.

1) Rendering the c.g., free and consequently caus-
ing the experimental conditions to approach those of real-
ity.

2) Avoiding profitless analytical discussions of the
various theoretically possible conditions and limiting them
to the calculation of the data obtained with each type of
airplane.

3) Investigating, on a sufficiently large scale (one-
twentieth to one-fifth,e.g.), the effect of the variation
in the absolute dimensions and determining the range of the
experiments on a reduced scale in the matter of stability,
in order to define the conditions of similitude from this
viewpoint.

4) Investigating not only the stability, but also the
controllability and the smoothness of operation,-a subjec-
tive notion frequently confounded with stability and behav-
ior in bad weather.

Flight tests take into account the effects of the wind
and supplement the insufficiency of the methods based on
similitude. These tests are applied to new types and to
airplanes made in quantity*. Attention is called to the
absolute lack of deductive documents regarding them. Al-
though there are, in France and in other countries, many
catalogs of wing profiles, there is hardly any systematic
presentation of laboratory tests of airplane models, sup-
plemented by flight tests. It is important for investiga-
tors and designers to compare the results obtained in
flight tests with the results obtained long before in the
office and laboratory. It would be a singular error to be-
lieve that hermitism in this matter would profit the aero-
nautic industry. Such publications constitute its best ad-
vertising, and the particularistic spirit, if it exists,
should yield in the interest of safety.

II

General character of the aerodynamic risk.
The critical zone is in the zone of operation.

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* On this point we refer the reader to a very useful paper
by Haegelen, "Du role du pilote d'essais," in the Revue de
la Société Générale Aéronautique, June, 1930, p. 1.

Recent progress. The experiences of the Inter-
national Races for Touring Airplanes in 1930.
New methods of solution. Airplanes with a wide
range of speed. The Schneider cup. Effect of
lightening the engine. Practical flight range
from the safety viewpoint.

The systematic investigation of stability problems is
therefore a complicated task, though some progress has been
made. In brief, the difficulties are due to the fact that
different regimes of flight are possible in the zone of op-
eration of the airplane, in particular at large angles,
when the effects of stability and controllability vanish
simultaneously. Hence it follows that two principal groups
of solutions can be imagined.

The first group, proceeding from investigations like
those we have just made, consists in improving the airplane
in its actual conditions of flight. Without deserting
these fundamental conditions, the airplane has, for several
years, made great progress in this direction. The Guggen-
heim Contest in America showed in 1929 what could be ex-
pected from experiments in the matter of stability at large
angles. The progress in general-purpose airplanes is still
more striking. In 1930 at the International Races for
Touring Airplanes, an experiment was tried, which was ex-
pected to enable the classification of airplanes according
to their qualities of flight at large angles, by their most
useful effect, the reduction of the distances required for
landing or taking off at steep slopes. It was a question
in both cases of flying over an obstacle 8 m. (26 ft.) high
within the shortest horizontal distance. In both tests the
best records were less than 130 m (426 ft.) in calm air*.
Of course, in order to judge the technical value of such a
performance, it would be necessary to consider the wing
loading (less than 30 kg/m² or 6.15 lb./sq.ft.), the power
loading and the maximum speed attained. They constitute,
nevertheless, a very useful basis, since the airplanes were
capable of attaining 160 km (about 100 miles) per hour with
two occupants in the series of long flights regularly ac-
complished across Europe.

The second group of solutions depends on another prin-
ciple. The cases of instability of regime are not excep-

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* In taking off, each airplane began with full throttle and
brakes locked, while, in landing, the distance was measured
to the stopping point of the airplane with brakes applied.

tional. They exist in metallurgy and in the strength of
materials. The radical solutions consist in rejecting the
critical zone outside the zone of operation. For this
type, the solution would consist in keeping the airplane
during flight at an angle of attack much farther, than is
actually the case, from the angle of maximum lift, while
eliminating, by the centering and dimensioning of the tail
surfaces, the tendency to instability in the vicinity of
zero lift. Many airplanes of this type are now appearing.

One of the seaplanes built in England for the
Schneider cup with a wing loading of nearly 200 kg/m^2
(41 lb./sq.ft.), attained a speed of 657 km (408.3 miles)
per hour. (This seaplane did not participate in the con-
test, but a little later broke the world speed record for
seaplanes.) At this speed, the seaplane flew at such an
angle of attack that the lift coefficient was between one-
twelfth and one-fifteenth of its maximum value. The speed
range was between 3.5 and 4, i.e., higher than any pre-
viously realized, many airplanes not attaining 2. It would
be an error to regard the technical filiation of the Stain-
forth seaplane as that of useless monsters.

If, in fact, the aerodynamic characteristics of the
winner of the Schneider cup* are conserved, the homolo-
gated airplanes are characterized by the constancy of the
product of the wing loading multiplied by twice the power
loading. For example the speed range would be conserved
for an airplane whose wing loading has been divided by 4
(which would reduce the landing speed to less than 90 km
(56 miles) per hour and whose power loading has been doub-
led. This would yield a whole series of airplanes between
the ratios 657/170 and 350/90.

Concrete examples have already shown this reasoning to
be well founded. Hawks' airplane traversed Europe at a
speed of 300 km (186 miles) per hour, and military deriva-
tives have already appeared in certain countries. For
these airplanes the excess motive power, as a stability re-
serve, plays a role similar to the freeboard reserve in the
safety of ships. It keeps the craft sufficiently remote
from the conditions which might jeopardize its equilibrium.

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* It would even be permissible to suppose it improved by
reason of the two following considerations: a) In the
Schneider-cup airplanes, the parasitic resistances play a
proportionally important role due to the reduced wing area;
b) The floats increase the parasitic resistance.

Even long-distance airplanes can gain by sacrificing a part of their radius of action to speed. A reduction of less than half the radius of action, which would still leave the possibility of a nonstop flight from Paris to India, would be accompanied, in fact, by a speed increase of about 30 per cent, and the practical range of operation would probably be much increased. The speed range, a notion as old as aviation itself, is therefore the subject of renewed interest today.

In this, the lightening of the engines plays an essential part. It can be judged by the course of the curves in Figure 4, in which the power variation is plotted against the speed range for different airplane types. Thus even the characteristics of the engines, as well as those of the new profiles and the search for new types of aircraft, aid in the solution of the central problem namely the development of the aerodynamic safety of airplanes.

The coefficient φ on the ordinate of Figure 4 is such that the power in kg-s/kg is given by $F/P = V_m\varphi$, F being the useful power. φ is therefore the quotient of E divided by L/D. V_m is the minimum speed. If f' indicates the hp and V'_m the speed in km/h, we have f' = $PV'_m\varphi/270$.

The different curves correspond to different airplanes or wing profiles. In order to compare the aptitude of different profiles for giving airplanes high speed ranges with the least possible power, the airplanes are assumed to be reduced to a single wing for some cases.

Note in particular: curve 2, very fine thin wing 76A (S.T.Aé. Bulletin No.12); curves 4 and 5, corresponding to the use of slotted wings (4, open; 5, closed), 207 Göttingen 1923, p. 59. The speed range for 4 corresponds to the minimum speed of 5. Note that, for very great speed ranges, the thin wing is better than the semi-thick slotted wing.

Curve 3 corresponds to an airplane of L/D ratio of 12 provided with the wing 76A. The power passes through a minimum for a range between 1 and 2. Hence the tendency for airplane designers to hold to a small speed range, when it is desired to produce a low-powered airplane. This is a mistake which entails a high landing speed, if it is desired to have a satisfactory cruising speed, and renders the airplane liable to stall.

Note also the high consumption of power for the wing with open slot near the speed range 3.2.

The general conclusion from this graph is that the speed range of 3 can not be exceeded without a considerable reduction in the motive power. This is fifteen times as large as the minimum power in curve 3. On the contrary, the effects of the profiles are very important in speed ranges below 3.

The engine of the Schneider-cup winner weighed only about 0.3 kg (0.66 lb.) per horsepower and the airplane had a thin wing.

Translation by Dwight M. Miner,
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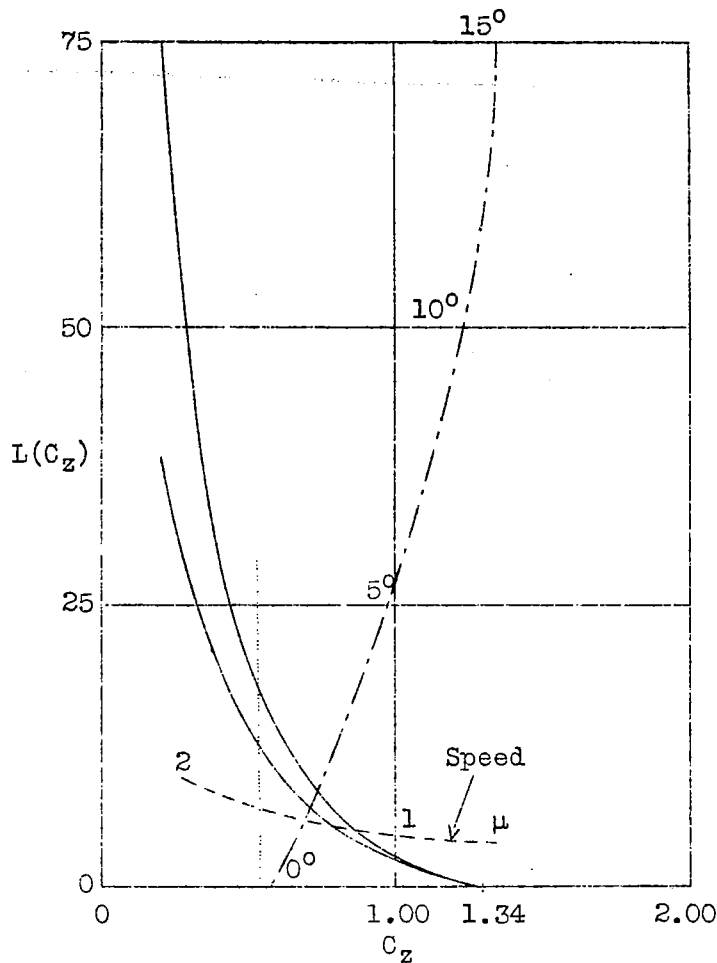
Fig.1 Length of
       horizontal
landing flight
plotted against
the lift coefficient
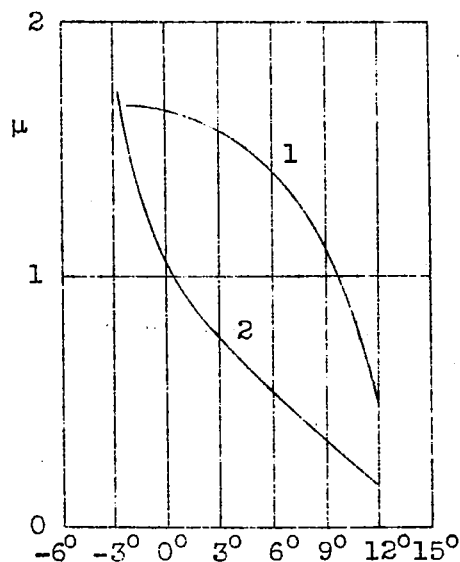at the beginning
of the horizontal
flight.

Fig.2 Coefficient
       of lateral
controllability μ
plotted against
the incidence for
an airplane provided
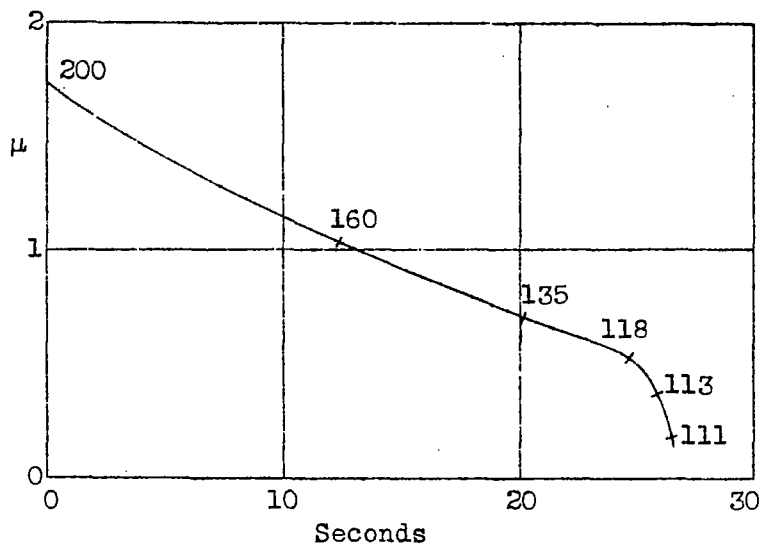with the wing 111A.
(S.T.Aé. Bulletin
 No.25.)

Fig.3 The same coefficient μ as in Figure 2, but here
       plotted against time, in the case of a maneuver
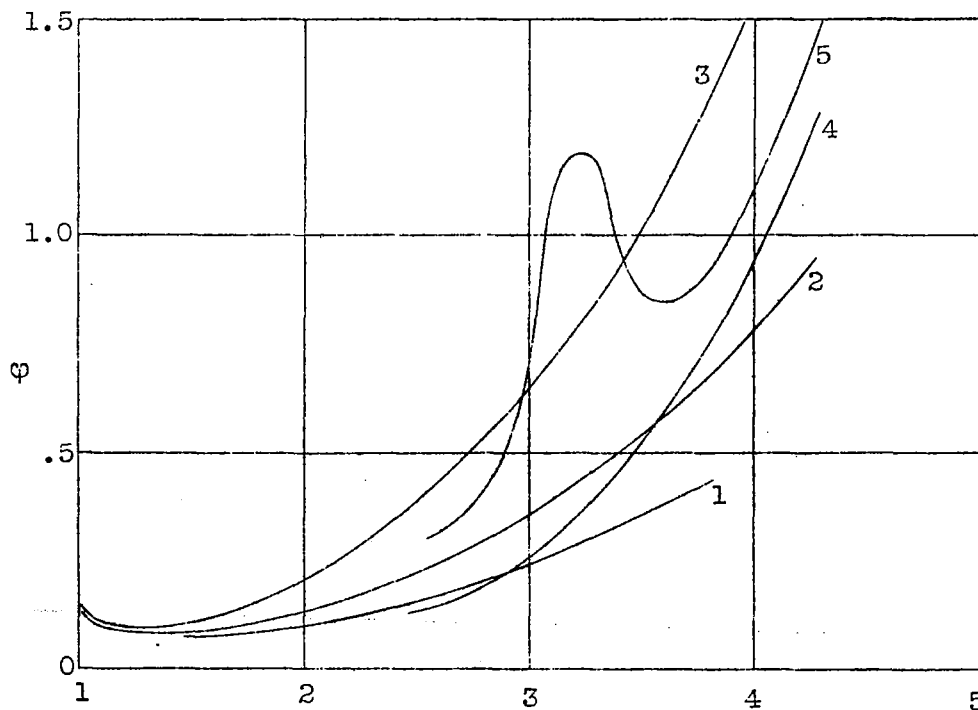   at constant lift (curve 2 of fig.2).

Fig.4 Propeller thrust plotted against speed range.
       The abscissa represents the speed range, i.e. the
ratio of the maximum speed to the landing speed. It is
expressed by the formula $\sqrt{C_zM/C_z} = E$, in which C_zM represents
the maximum value of C_z.